

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2017/2018

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY (EE)

30 MAY 2018
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 7 and 8 for a list of physical constants, formulas, and the error function table.

Question 1

- (a) Elaborate the principal reason for using semiconductor as active material in microelectronic devices. Among different semiconductor materials, provide **THREE** reasons why silicon (Si) is the dominant material in microelectronic industries compared to germanium (Ge). [5 marks]
- (b) Czochralski (CZ) technique is the main technology used in the growth of monocrystalline silicon (Si) ingot for microelectronic applications.
- (i) Based on the diagram provided in Figure Q1(b) below, describe the CZ monocrystalline growth process for a doped Si ingot. [8 marks]

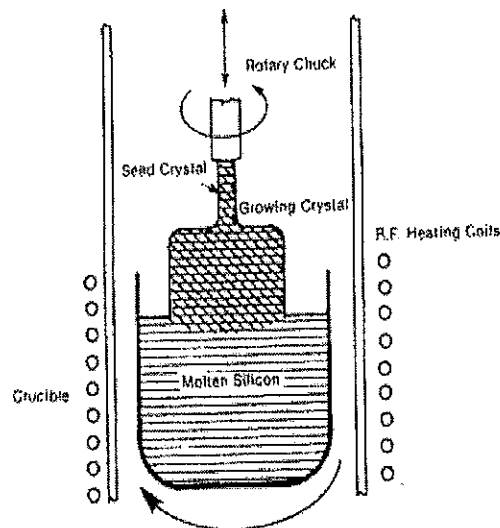


Figure Q1(b): Schematic diagram for Czochralski crystal growth process.

- (ii) In the CZ monocrystalline growth process, explain how doping uniformity, crystal perfection and diameter control for the doped Si ingot can be achieved. [2 marks]
- (iii) Describe **ONE** advantage and **ONE** disadvantage of the CZ technique in the growth of monocrystalline Si ingot, respectively. [2 marks]
- (c) A boule of doped monocrystalline Si ingot is pulled from the melt composed of Si and phosphorus (P) dopant in a CZ crystal growth process. After the Si boule is pulled, it is sliced into thin wafers. The wafer taken from the top of the boule has a P concentration of $1.3 \times 10^{15} \text{ cm}^{-3}$. The segregation coefficient (k) for P is given as 0.35. Determine the doping concentration of the Si wafer taken from the position corresponding to 68 % of the initial charge solidified. [3 marks]

Continued

Question 2

- (a) Illustrate the schematic diagram of a projection aligner system. Describe **TWO** advantages and **TWO** disadvantages of the projection aligner system in optical lithography patterning process. [2+4 marks]
- (b) Given a resist constant, K , of 0.65 and a numerical aperture, NA , of 0.2 for a projection aligner system, determine the minimum feature size attainable with available exposure wavelengths of 50 nm, 80 nm, 130 nm, and 270 nm, respectively. With the available options, identify the suitable exposure wavelength for patterning transistors with channel length of 200 nm. [5 marks]
- (c) Figure Q2(c) illustrates an exposure process through optical mask on a substrate deposited with a thin film, which is spin coated with photoresist on top of the thin film. For the **positive** and **negative** photoresist, sketch the subsequent structures after the photoresist development and film etching process, respectively. [4 marks]

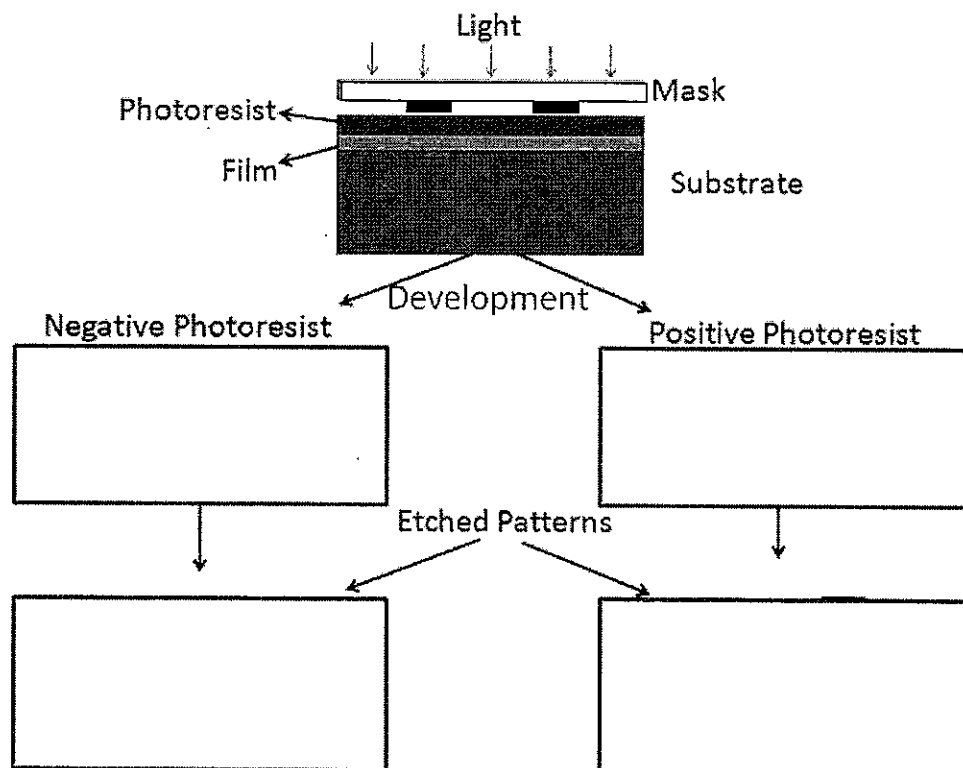


Figure Q2(c): Optical patterning of thin film using positive and negative photoresist.

Continued

Question 2

- (d) Figure Q2(d) depicts the schematic cross-section of a n-type metal-oxide-semiconductor field-effect transistor (MOSFET) on p-type silicon substrate. The gate contact for the MOSFET is made of polysilicon and the drain and source contacts are made of aluminum metal.

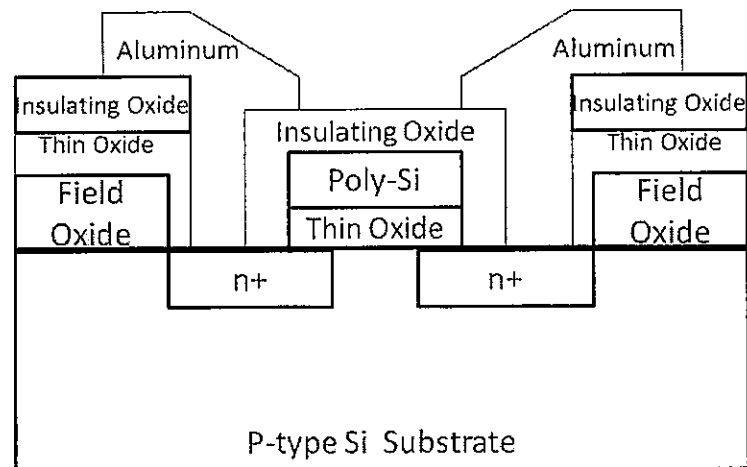


Figure Q2(d): Schematic cross-section of a n-type metal-oxide-semiconductor field-effect transistor (MOSFET) on p-type silicon substrate.

- (i) Design a self-aligned fabrication process flow for the MOSFET depicted in Figure Q2(d). Illustrate each processing step starting from the p-type silicon substrate. [11 marks]
- (ii) Identify a low cost and simple physical vapor deposition (PVD) technique to deposit the aluminum metal. Briefly describe the working principles of the PVD technique. [1+3 marks]

Continued

Question 3

- (a) A p-type silicon substrate with doping concentration of $3 \times 10^{15} \text{ atom cm}^{-3}$ is doped by deposited a fixed quantity of Group V material. An n-region with junction depth of $1.023 \mu\text{m}$ is formed. The impurity concentration at the surface of wafer is $1 \times 10^{18} \text{ atoms cm}^{-3}$ and diffusion time is 75 minutes.

Table Q3(a) Diffusion coefficient (cm^2/sec) of dopants in silicon

Dopant	Temperature	
	1100°C	1200°C
Phosphorus	1.5×10^{-13}	1.5×10^{-12}
Arsenic	1.5×10^{-14}	1.5×10^{-13}
Antimony	1.0×10^{-14}	1.0×10^{-13}

- (i) Calculate the diffusion coefficient of dopants which is needed to form the n-region. According to Table Q3(a), determine the material and the corresponding temperature to be used in the doping process. [4 marks]
- (ii) Determine the dose of the dopant for the diffusion process, in cm^{-2} . [2 marks]
- (b) Briefly explain the ion implantation system. [5 marks]
- (c) Aluminium is the commonly used material to form metal contact on silicon substrate in integrated circuit fabrication process. Based on the current-voltage characteristic, briefly explain 3 possible types of aluminium contacts can be formed on silicon. [6 marks]
- (d) Briefly explain electromigration and suggest a method to overcome the issue. [3 marks]

Continued

Question 4

- (a) After wafer fabrication and packaging process, the fabricated devices will undergo a series of testing such as production quality test, functional test, parametric test and accelerated test. Categorise those tests into **TWO** groups and then give definition of each test. [6 marks]
- (b) With the aid of a series of diagram, explain the procedures to do thermocompression bonding. Give one problem that will be faced during thermocompression bonding. [10 marks]
- (c) Explain why packaging is needed for an integrated circuit? Give **THREE** types of package which are commonly used. [7 marks]
- (d) $1.8 \times 1.8 \text{ mm}^2$ die bipolar transistors are designed and fabricated on a 180 mm diameter wafer with a defect density of 80 defects/cm². The cost of packaging and testing is RM3.20 per die and the cost of fabrication processes is RM75. Calculate the total manufacturing cost if the defects are uniformly distributed. [7 marks]

Continued

APPENDIX

Physical Constants:Avogadro number, $N_{\text{avo}} = 6.02217 \times 10^{23} \text{ mol}^{-1}$ Boltzmann constant, $k = 1.380622 \times 10^{-23} \text{ J K}^{-1} = 8.61712 \times 10^{-5} \text{ eV K}^{-1}$ Electronic charge, $e = 1.60219 \times 10^{-19} \text{ C}$ Electron rest mass, $m_0 = 9.10956 \times 10^{-31} \text{ kg}$ Electron volt, $1 \text{ eV} = 1.60219 \times 10^{-19} \text{ J}$ Si yield strength = $2 \times 10^7 \text{ dynes cm} = 7 \text{ GPa}$ Latent heat of fusion for Si, $L = 340 \text{ cal g}^{-1}$ Thermal conductivity of Si, $k = 0.21 \text{ W cm}^{-1} \text{ }^\circ\text{C}^{-1}$ Amount of heat of 1 calorie = 4.14 J Density of bulk Si = 2.33 g cm^{-3} Density of molten Si = 2.53 g cm^{-3} Electric current of $1 \text{ A} = 1 \text{ Cs}^{-1}$ Atomic mass unit of $1 \text{ amu} = 1.66053 \times 10^{-27} \text{ kg}$ Magnetic flux density of $1 \text{ T} = 1 \text{ Wb m}^{-2} = 10^4 \text{ G}$ Angstrom unit of $1 \text{ \AA} = 1 \times 10^{-10} \text{ m} = 0.1 \text{ nm} = 1 \times 10^{-4} \text{ }\mu\text{m}$ Permittivity of free space = $8.85 \times 10^{-14} \text{ F cm}^{-1}$ Pressure of $1 \text{ Torr} = 133.32237 \text{ Pa}$ **Formulas:**

$C = kC_0(1-x)^{k-1}$	$C_s = \frac{Q_T}{\sqrt{\pi Dt}}$
$\sigma = pq\mu$	$N(x) = \frac{Q_0}{\sqrt{2\pi}\Delta R_P} e^{\left[\frac{-1}{2}\left(\frac{x-R_P}{\Delta R_P}\right)^2\right]}$
$W_{min} = \sqrt{k\lambda g}$ $W_{min} = K\{\lambda/NA\}$	$Y = e^{-D_0 A}$
$C(x,t) = C_s \operatorname{erfc}\left[\frac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\frac{1 - e^{-D_0 A}}{D_0 A}\right]^2$
$Q = 2C_s \sqrt{\frac{Dt}{\pi}}$	$Y = \left[\frac{1 - e^{-2D_0 A}}{2D_0 A}\right]$
$C(x,t) = \frac{Q_T}{\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$	$N = \frac{\pi(r-S)^2}{S^2}$
$x_j = 2\sqrt{Dt \ln \frac{C_s}{C_b}}$	

Continued

Values of the error function $\text{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3494	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8427	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\text{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi} t} \exp(-t^2)$

$\text{erfc}(t) = 1 - \text{erf}(t)$

End of Paper

